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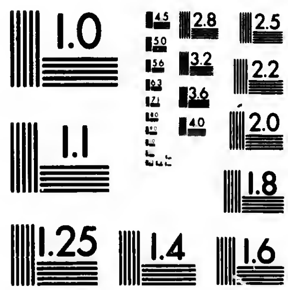

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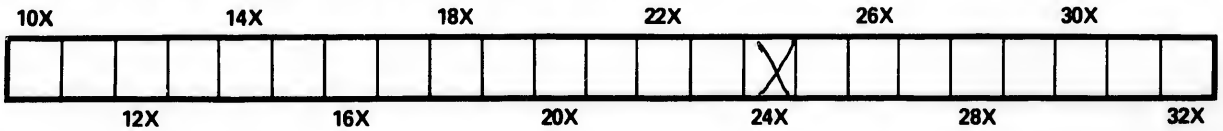

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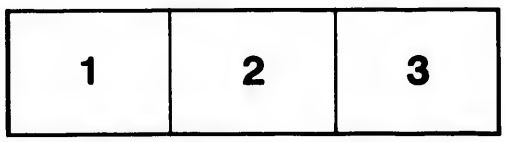

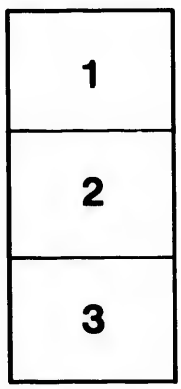

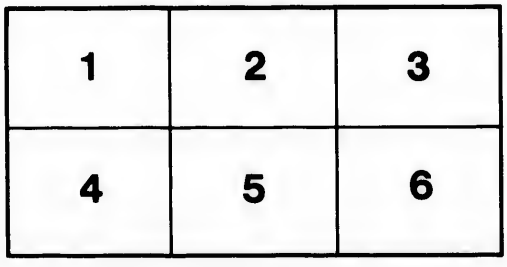

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[*From the "Canadian Journal.*]

ON THE DIURNAL AND ANNUAL

VARIATIONS OF TEMPERATURE

AT HALIFAX, NOVA SCOTIA.

BY G. T. KINGSTON, M.A.,
Director of the Magnetic Observatory, Toronto.

FROM BI-HOURLY OBSERVATIONS BY F. ALLISON, M.A., DURING THE THREE YEARS 1867-69.

For developing the climatology of this country, two or more chief stations in each province are needed, differing from ordinary stations, partly in the extent of their instrumental appliances, and partly in the frequency of the observations.

One of the leading objects of these chief stations has been carried out by Mr. Allison, of Halifax, by making the observations from which the results given in this paper are derived. The nature and purpose of these results will be understood from the following considerations.

The majority of observers, being engaged in their various callings, cannot usually observe often enough in the day, nor persevere for a sufficient number of years for the collection of materials adequate for the calculation of the normal values of the elements proper to their several stations.

Their observations can however to a great extent be made comparable with those carried on more frequently, and extended through a long term of years, by applying corrections deduced from the observations made at a few well equipped chief stations and continued through a long series of years, during a portion of which the observations have been taken at *equal* intervals not exceeding three hours.

The corrections are of two kinds. First, the corrections by which compensation is made for the insufficient *frequency* of the observations at ordinary stations; and, secondly, those which compensate their

Toronto, 1871

insufficient *continuance*. It is with the former class of corrections that this article is concerned.

Mr. Allison has forwarded to Toronto for reduction a series of thermometric readings, made by him or under his direction at every even hour (with a very few exceptions) during the three years 1867–69.

In a few instances, when readings at 2 a.m. and 4 a.m. were not taken, the observations of the whole day were set aside. As these, *including Sundays*, were only 22, the unbroken days in the three years amounted to 1,074, and the readings employed in the calculation 12,888; giving, for each month, 80 or 90 readings for each of the twelve bi-hourly means.

The primary object of the computation being to learn for each month the quantity by which the temperature at each hour differs from the mean temperature of the month for all hours collectively, interpolating formulæ for each month have been constructed, by aid of which the most probable temperature could be computed for any instant in the twenty-four hours.

The following is the general type of the formulæ, where T_n represents the required temperature at any time (n) reckoned from midnight, the unit of time being one hour, t_0, t_1, t_2, &c., certain constant temperatures, and c_1, c_2, &c., certain constant angles derived from the twelve bi-hourly mean temperatures for the particular month under consideration.

$$T_n = t_0 + t_1 \sin(n \times 15^\circ + c_1) + t_2 \sin(2n \times 15^\circ + c_2) + t_3 \sin(3n \times 15^\circ + c_3)$$
$$+ t_4 \sin(4n \times 15^\circ + c_4) + t_5 \sin(5n \times 15^\circ + c_5) + t_6 \sin(6n \times 15^\circ + c_6)$$

The values of the constants t_0, t_1, &c., c_1, c_2, &c., are given for each month in the following table.

TABLE I.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
t_0	19.63	23.18	27.13	37 20	48.15	58.52	64.35	64.13	58.19	46.01	36.02	25.21
t_1	3.38	4.55	6.11	0.86	7.81	8.42	8.64	8.18	6.87	5.58	2.77	2.64
t_2	1.32	1.37	1.72	1.35	1.13	0.66	0.99	1.35	1.81	1.78	1.25	1.08
t_3	0.32	0.25	0.12	0.36	0.60	0.78	0.78	0.74	0.42	0.07	0.20	0.38
t_4	0.15	0.16	0.23	0.02	0.17	0.39	0.21	0.21	0.28	0.22	0.04	0.08
t_5	0.15	0.13	0.11	0.14	0.21	0.07	0.10	0.13	0.14	0.30	0.17	0.07
t_6	0.02	0.02	0.08	0.02	0.03	0.06	0.06	0.01	0.10	0.03	0.02	0.06

TABLE I.—(*Continued.*)

c_1	221° 03′	225° 59′	233° 03′	237° 34′	242° 33′	240° 14′	238° 41′	240° 39′	241° 46′	239° 32′	235° 16′	240° 42′
c_2	60 32	62 43	72 43	67 48	83 23	77 40	69 55	68 21	64 26	71 58	72 17	59 51
c_3	204	191	24	84	54	54	60	54	76	333	261	224
c_4	101	210	182	153	123	99	127	183	225	243	104	97
c_5	32	23	75	104	275	286	276	129	0	17	33	16
c_6	270	270	90	270	270	270	270	90	90	90	270	270

Taking each monthly formula separately, and giving to n successively the values 0, 1, 2, 3, &c., we obtain for that month the mean normal temperatnres for each of the twenty-four hours, as far as the normals can be procured from the observations of only three years.

The results are given in the following table, in which the numbers in the final column for the year are the arithmetic means from the corresponding twelve monthly numbers.

TABLE II.

Monthly Mean Normal Temperatures, at Halifax, for each of the twenty-four hours, from Bi-hourly Observations in the three years 1867–69.

Hour.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	°	°	°	°	°	°	°	°	°	°	°	°	°
Mldn.	18.83	20.90	24.12	33.05	42.73	52.75	58.79	58.07	54.07	42.78	34.85	23.63	38.79
1a.m.	18.24	20.32	23.11	32.15	42.11	51.92	57.78	58.04	53.53	42.51	34.05	23.47	38.15
2 "	17.40	19.74	22.09	31.36	41.44	50.89	56.64	57.13	52.82	41.80	34.14	23.28	37.40
3 "	16.70	19.28	21.55	30.85	40.73	50.06	55.88	56.63	52.27	41.16	33.59	23.06	36.81
4 "	16.49	19.06	21.39	30.76	40.49	50.15	55.96	56.61	52.04	40.83	33.34	23.05	36.68
5 "	16.63	19.12	21.35	31.06	41.33	51.51	57.01	57.69	52.21	40.67	33.38	23.27	37.08
6 "	16.72	19.23	21.64	32.12	43.26	53.69	58.77	58.32	53.06	41.49	33.48	23.45	37.94
7 "	16.75	19.58	22.53	33.94	45.71	56.08	61.03	60.57	54.79	42.62	33.70	23.52	39.25
8 "	17.20	20.54	24.98	36.24	48.21	58.46	63.78	63.61	57.21	44.36	34.45	23.88	41.08
9 "	18.47	22.26	27.65	38.68	50.66	60.93	66.72	66.70	59.85	46.94	35.90	24.91	43.30
10 "	20.39	24.30	30.24	40.59	53.02	63.36	69.23	69.17	62.30	49.56	37.60	26.38	45.60
11 "	22.07	26.09	32.30	42.77	54.95	65.14	70.90	70.78	64.21	51.42	38.91	27.74	47.27
Noon.	23.38	27.44	33.67	43.83	56.04	66.23	71.90	71.83	65.36	52.29	39.61	28.70	48.36
1p.m.	24.16	28.44	34.10	44.91	56.24	66.65	72.81	72.54	65.92	52.62	39.86	29.17	48.96
2 "	24.38	29.03	34.15	45.19	55.96	66.66	73.30	72.88	66.22	52.77	39.73	29.04	49.11
3 "	23.96	28.90	33.75	44.67	55.55	66.49	73.17	72.65	66.06	52.35	39.13	28.28	48.74
4 "	23.01	27.90	32.68	43.31	54.87	66.08	72.33	71.65	64.78	50.88	38.11	27.19	47.73
5 "	21.88	26.35	30.97	41.73	53.46	65.04	70.81	69.84	62.27	48.65	37.03	26.17	46.18
6 "	20.98	24.83	29.15	39.84	51.14	62.95	68.53	67.37	59.48	46.69	36.29	25.38	44.39
7 "	20.37	23.74	27.67	37.76	48.49	59.98	65.66	64.63	57.44	45.65	35.92	24.81	42.68
8 "	19.95	23.09	26.52	35.93	46.38	57.08	62.89	62.19	56.22	45.10	35.64	24.45	42.29
9 "	19.66	22.66	25.61	34.80	45.10	55.07	60.96	60.57	55.37	44.37	35.30	24.27	40.30
10 "	19.34	22.07	25.03	34.24	44.26	53.99	60.00	59.87	54.72	43.51	34.99	24.10	39.68
11 "	19.13	21.48	24.68	33.32	43.47	53.38	59.45	59.52	54.36	42.95	34.86	23.85	39.20
Mean	19.83	23.18	27.13	37.20	48.15	58.52	64.35	64.13	58.19	46.01	36.02	25.21	42.33

If the difference of each hourly normal in excess or defect from the means for twenty-four hours given at the foot of each column be taken, we have the diurnal variations given in Table III.

TABLE III.

Mean Diurnal Variations of Temperature, at Halifax, for each month and for the year, from Bi-hourly Observations in the years 1867-69.

Hour.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°	°	°	°	°	°
Midn.	−1.00	−2.28	−3.01	−5.15	−5.42	−5.77	−5.56	−5.16	−4.12	−3.23	−1.17	−1.58	−3.54
1a.m.	−1.59	−2.86	−4.02	−5.05	−6.04	−6.09	−6.57	−6.09	−4.66	−3.50	−1.37	−1.74	−4.18
2 "	−2.43	−3.44	−5.04	−5.84	−6.71	−7.03	−7.71	−7.00	−5.37	−4.15	−1.88	−1.93	−4.93
3 "	−3.13	−3.90	−5.58	−6.35	−7.42	−8.46	−8.47	−7.50	−5.92	−4.85	−2.43	−2.15	−5.52
4 "	−3.34	−4.09	−5.74	−6.50	−7.66	−8.37	−8.39	−7.52	−6.15	−5.18	−2.68	−2.16	−5.65
5 "	−3.20	−4.06	−5.78	−6.14	−6.82	−7.01	−7.34	−7.04	−5.98	−5.04	−2.64	−1.94	−5.25
6 "	−3.11	−3.95	−5.49	−5.68	−4.89	−4.83	−5.58	−5.81	−5.13	−4.52	−2.54	−1.76	−4.30
7 "	−3.08	−3.60	−4.30	−3.26	−2.44	−2.44	−3.32	−3.56	−3.40	−3.49	−2.32	−1.69	−3.08
8 "	−2.63	−2.64	−2.15	−0.90	+0.06	−0.06	−0.57	−0.52	−0.98	−1.65	−1.67	−1.33	−1.25
9 "	−1.36	−0.92	+0.52	+1.38	+2.51	+2.41	+2.37	+2.57	+1.66	+0.93	−0.12	−0.30	+0.97
10 "	+0.47	+1.12	+3.11	+3.39	+4.87	+4.78	+4.88	+5.04	+4.11	+3.55	+1.58	+1.17	+3.17
11 "	+2.24	+2.91	+5.17	+5.57	+6.80	+6.62	+6.55	+6.65	+6.02	+5.41	+2.89	+2.53	+4.94
Noon.	+3.56	+4.26	+6.44	+6.63	+7.89	+7.71	+7.64	+7.70	+7.17	+6.28	+3.59	+3.49	+6.03
1p.m.	+4.33	+5.20	+6.97	+7.71	+8.09	+8.13	+8.46	+8.41	+7.73	+6.61	+3.84	+3.96	+6.62
2 "	+4.55	+5.85	+7.02	+7.99	+7.81	+8.14	+8.95	+8.75	+8.03	+6.76	+3.71	+3.83	+6.78
3 "	+4.13	+5.72	+6.62	+7.37	+7.40	+7.67	+8.87	+8.52	+7.87	+6.34	+3.11	+3.07	+6.41
4 "	+3.18	+4.72	+5.55	+6.11	+6.72	+7.56	+7.98	+7.52	+6.59	+4.87	+2.09	+1.98	+5.40
5 "	+2.05	+3.17	+3.84	+4.53	+5.31	+6.52	+6.46	+5.71	+4.68	+2.64	+1.01	+0.96	+3.85
6 "	+1.15	+1.65	+2.02	+2.64	+2.99	+4.43	+4.18	+3.24	+1.20	+0.08	+0.27	+0.17	+2.06
7 "	+0.54	+0.50	+0.51	+0.50	+0.34	+1.46	+1.31	+0.50	−0.75	−0.30	−0.10	−0.40	+0.35
8 "	+0.12	−0.00	−0.00	−1.27	−1.77	−1.44	−1.40	−1.94	−1.07	−0.01	−0.28	−0.76	−1.04
9 "	−0.23	−0.58	−1.52	−2.40	−3.05	−3.45	−3.39	−3.56	−2.82	−1.64	−0.72	−0.94	−2.03
10 "	−0.49	−1.11	−2.16	−2.96	−3.80	−4.53	−4.35	−4.26	−3.47	−2.56	−1.03	−1.11	−2.65
11 "	−0.79	−1.70	−2.45	−3.88	−4.68	−5.14	−4.90	−4.61	−3.83	−3.06	−1.16	−1.36	−3.13

One of the uses of Table III. is to supply corrections to the monthly means derived from less frequent observations at the *same station* in other years, so as to render them comparable with the means derived from an hourly or bi-hourly series.

This has been done in the case of the temperatures at Halifax in 1870, when the observations were taken at equal intervals of four hours, commencing at 4 a.m. The corrections (which are very small) were applied to the monthly means for 1870, and the corrected means were then combined with the monthly means for the years 1867, 1868, and 1869, as shown in the following table.

	Jan.	Feb.	Mar.	Apr.	May.	June.
1870, uncorrected	29.48	23.79	28.53	40.79	46.39	59.18
Corrections for Diurnal Variation	+0.02	+0.02	−0.08	+0.02	+0.03	+0.06
1870, corrected for Diurnal Variation	29.50	23.81	28.45	40.81	46.42	59.24
1867—1870	22.24	23.34	27.46	38.10	47.72	58.70

	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1870, uncorrected	64.56	64.27	56.54	48.15	38.02	30.78	44.28
Corrections for Diurnal Variation	+0.06	−0.01	−0.09	−0.03	+0.02	+0.06	+0.01
1870, corrected for Diurnal Variation	64.62	64.26	56.45	48.12	38.04	30.84	44.29
1867—1870	64.42	64.16	57.76	46.54	36.75	26.61	42.82

An interpolating formula being construeted from the twelve monthly means in the lowest line, on the assumption that they are the temperatures proper to the *middle days* of the several months; if the coefficients calculated on this erroneous assumption be multiplied respectively by the following factors, the expression given below is obtained, in which T_n denotes the daily mean temperature at any time n, reckoned from January 15, the unit of time being the twelfth part of the year.

$$\frac{\Pi}{12} \div \sin\frac{\Pi}{12}\ ; \qquad \frac{2\,\Pi}{12} \div \sin\frac{2\,\Pi}{12}\ ; \quad \&c. \qquad \frac{6\,\Pi}{12} \div \sin 6\,\frac{\Pi}{12}\ ;$$

$$T_n = 42^\circ.82 + 21^\circ.82 \sin(n \times 30^\circ + 256^\circ.48) + 0^\circ.77 \sin(2n \times 30^\circ + 55^\circ)$$
$$+ 0^\circ.18 \sin(3n \times 30^\circ + 252^\circ) + 0^\circ.25 \sin(4n \times 30^\circ)$$
$$+ 0^\circ.89 \sin(5n \times 30^\circ + 8^\circ) + 0^\circ.14 \sin(6n \times 30^\circ + 270^\circ)$$

From the preceding equation which, by giving suitable values to (n), expresses the *normal* daily mean temperature at Halifax on every day in the year, the mean temperatures of the warmest and coldest days are found, together with the days of their occurrence, and the days on which the daily mean passes through its mean annual value.

Warmest day, August 28. Mean temperature, 64°.90.

Coldest day, January 13, 14. Mean temperature, 21°.95.

In Spring, the mean of the day is below the mean of the year on April 29, and exceeds it on April 30.

In Autumn, the mean of the day passes through its annual value between October 25 and October 26.

TABLE IV.

Combination.	Jan.	Feb.	Mar.	Apr.	May.	June.
Arithmetic Means from 7, 2, 9	+0.41	+0.56	+0.49	+0.78	+0.77	+0.75
7, 2, 9, 9	+0.25	+0.27	−0.08	−0.02	−0.18	−0.30
6, 2, 10	+0.32	+0.20	−0.19	−0.02	−0.32	−0.41

Combination.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Arithmetic Means from 7, 2, 9	+0.75	+0.54	+0.60	+0.54	+0.22	+0.40	+0.56
7, 2, 9, 9	−0.29	−0.48	−0.25	−0.00	−0.01	+0.06	−0.09
6, 2, 10	−0.33	−0.44	−0.19	−0.09	+0.05	+0.32	−0.09

In Table IV are shown the errors in the approximate monthly means when the daily mean is considered as the simple arithmetic means of the temperatures observed at 7 a.m., 2 p.m. and 9 p.m., and of those observed at 6 a.m., 2 p.m. and 10 p.m.; and also when the daily mean is taken as equal to the *fourth* part of the sum of the temperatures at 7 a.m., 2 p.m., and *twice* the temperature at 9 p m.

It is seen that the arithmetic mean of observations at 7 a.m., 2 p.m. and 9 p.m., gives a result too high by 0.° 56 on the average of all months, and nearly eight-tenths too high from April to July.

The arithmetic mean of observations at 6 a.m., 2 p.m. and 10 p.m., is in no case more than half a degree in error; it is too high from November to February, and too low during the rest of the year, the average error irrespective of sign being a quarter of a degree, and the error in the annual mean less than one-tenth in defect.

When the observation at 9 p.m. is reckoned *twice*, the greatest error which occurs in any month is slightly greater, but the average error of the twelve monthly means, the signs of the errors being disregarded, is 0.° 18, and the error in the annual mean the same as in the preceding case.

These results accord in their general character with the experience of other places at which the observations have been sufficiently frequent for determining the diurnal variations.

As regards suitability for yielding daily means, 7, 2, 9, 9, and 6, 2, 10, may be regarded as of nearly equal merit; and as 7, 2, 9, are in many respects more convenient to observers than the other combination, and less liable therefore to interruptions, these hours are recommended to those observers in Canada who read their instruments three times each day.*

The numbers in Table III, as the title states, are the *monthly means* of the diurnal variations, and are only adapted therefore for the reduction of *monthly* means at single hours to monthly means for all hours, and for the converse reduction. Comparison of like hours in contiguous months will show a considerable difference in the analogous variations. To correct *daily* means, therefore, it is necessary to possess tables in which diurnal variations are given at much shorter intervals. As three years is scarcely sufficient for the elimination of accidental irregularities, the computation of the diurnal variations for every fifth day

* 7 a.m., 2 p.m. and 9 p.m., have been adopted for many years by the Smithsonian Institution.

has been postponed till at least two more years have been added to the series. For a like reason, the discussion of questions relating to the comparative variability of different months, and of daily means at different parts of the year, has not been undertaken. The collection of suitable materials for Halifax is however in progress, as Mr. Allison has been observing at equal intervals of three hours since the beginning of 1871.

It was stated at the commencement of this article, that besides the corrections for diurnal variations, or those needed to compensate for the insufficient *frequency* of the observations, corrections are also required in order that observations taken during a few years may be rendered comparable with those continued during a long series of years.

In procuring data for the second class of corrections some other observers have made considerable progress; but in order to give full effect to their past work, it is requisite that they should undertake for a few years at least equidistant observations at intervals not exceeding three hours. Among these, Mr. Murdoch, C. E., of St. John's, New Brunswick, who has been actively engaged in Meteorology for more than ten years, is about, it is believed, to commence a system of three-hour intervals. Should he persevere in this undertaking for four or five years, his series will be inferior to that of no station now in correspondence with Toronto.

It is much to be desired also that a three-hour system could be established under Dr. Smallwood, at Montreal, and Capt. Ashe, at Quebec, in order that their observations in past years may be more effectively utilized.

In connection with the subject of diurnal variations it is satisfactory to mention that, through the kindness of the Rev. Dr. Fyfe, President of the Canadian Literary Institute, the Baptist College at Woodstock, Ontario, Mr. Montgomery, the mathematical tutor, with other officers of the establishment, have been engaged for some months in taking observations of the temperature, day and night, at equal intervals of three hours. Mr. Montgomery is fully alive to the importance of accuracy; and as his arrangements are very excellent, it is anticipated that valuable aid will be supplied by his labours towards the reduction of observations in other parts of West Ontario.